

Performance Comparisons of Safeguard Detector Designs

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*A U.S. Department of Energy laboratory
managed by The University of Chicago*



Safeguard Detector Criteria

Discussion from May 2006 Workshop

Relevant Issues for Rate Based Analysis

- Deployment
- Operation
- Stability
 - Systematic effects on Stability of daily rate versus time <1% after calibrations
- Detector Performance
 - Signal
 - *attain 1% statistical error in 1-4 weeks*
 - Background
 - *Set energy threshold to satisfy rate and stability criteria above*

Relevant Issues for Spectral Analysis

- Deployment
- Operation
- Stability
 - Stability of energy spectrum versus time after calibrations
- Detector Performance
 - Signal
 - *Signal rate > 2000 ev. / day*
 - *Uniform spatial response*
 - Energy response
 - Event selection efficiency
 - Background
 - *Energy Threshold low enough to do shape analysis (?)*
 - *Background uncertainty less than statistical uncertainty in each bin*



Basis of this Study

■ Montecarlo Simulation

- Based on GLG4Sim (<http://neutrinos.phys.ksu.edu/~GLG4sim/>)
 - *Open source Geant4 based simulation package specifically dedicated to liquid scintillator antineutrino detectors*
 - *Includes libraries developed by KamLAND and others*
- Used latest scintillator development and material and optical properties from Double Chooz Collaboration

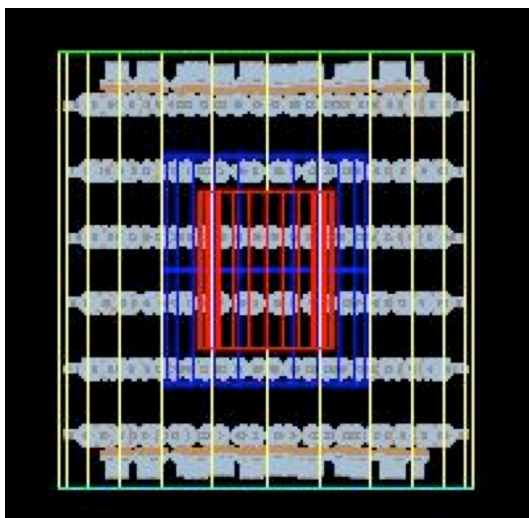
■ Detector designs derived from discussions with many groups

- Use current technologies
 - *Gd doped liquid scintillator target volumes*
 - *Some designs use an un-doped scintillator “gamma-catcher”*
 - *8” PMTs within a 1 m inactive buffer to shield radioactivity*
- Maximize signal, minimize footprint
 - *2 ton fiducial volume – provide adequate signal out to ~60m*
 - *Keep overall dimensions less than 3—4 m*



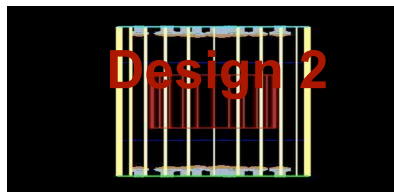
Detector Designs

Design 1



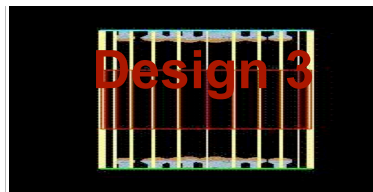
Basic Physics Design
282 PMTs
Diameter 4 m
Height 4.2 m

Design 2



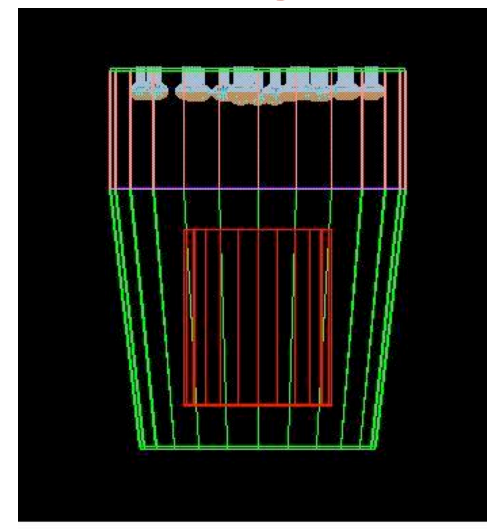
Two-Ended Readout
+ Gamma-Catcher
30 PMTs
Diameter 2 m
Height 4.2 m

Design 3



Two-Ended Readout
NO Gamma-Catcher
30 PMTs
Diameter 2 m
Height 3.5 m
Target Volume 4.71 m³

Design 4



Single-Ended Readout
+ Gamma-Catcher
24 PMTs
Diameter 2.5 m
Height 3.2 m



Performance Tests

■ Neutron Identification Efficiency

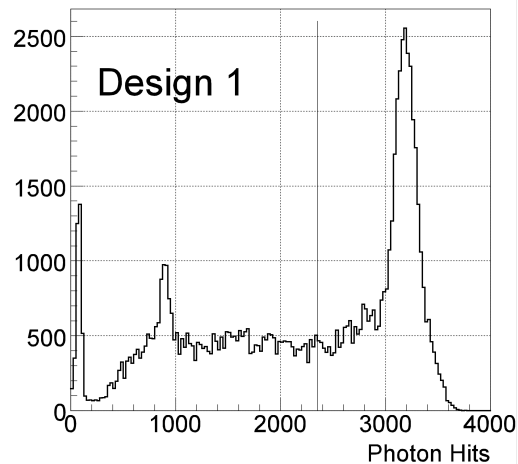
- Generate uniform distribution of neutrons over target volume
 - *Kinetic energy of 2.5 MeV*
 - *Select events where neutron stops or is captured within target*
 - *Sum all photon hits within 100ns*
- Identify neutron capture on gadolinium vs. all other processes
 - *Define threshold as 2/3 between fitted peaks of neutron captures on proton and gadolinium*
 - *Investigate spatial uniformity of neutron identification*

■ Uniformity of Positron Energy Response

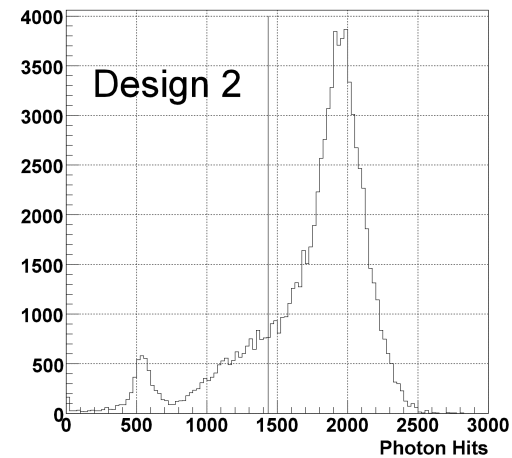
- Generate uniform distribution of positrons over target volume
 - *Kinetic energy of 1.5 and 3.5 MeV*
 - *Sum all photon hits within 100ns*
- Compare relative deviations to mean response as a function of vertex position



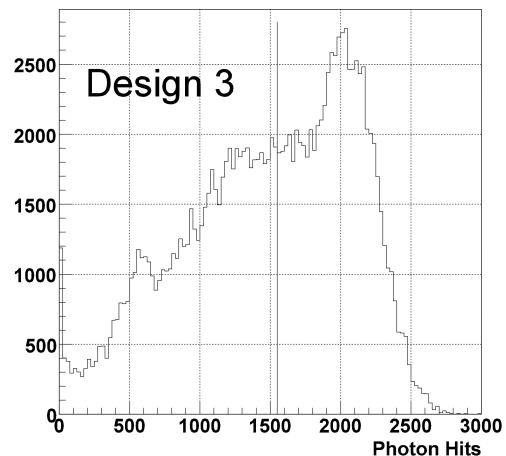
Neutron Identification Efficiency



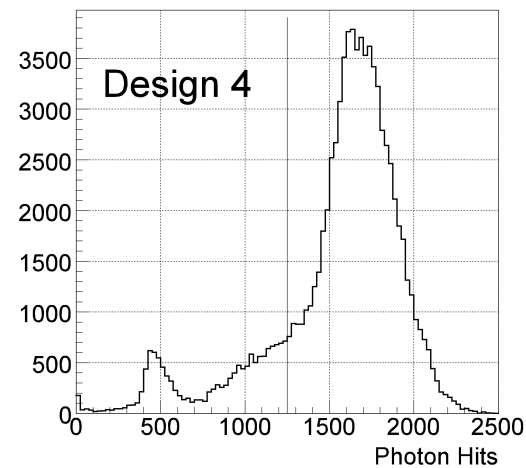
51.6%



80.4%



50.2%

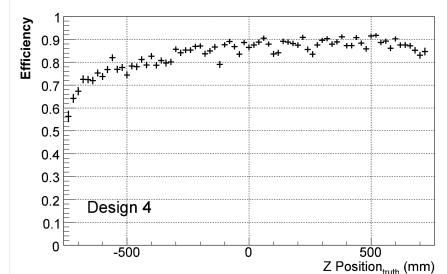
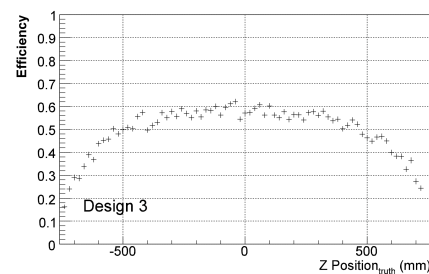
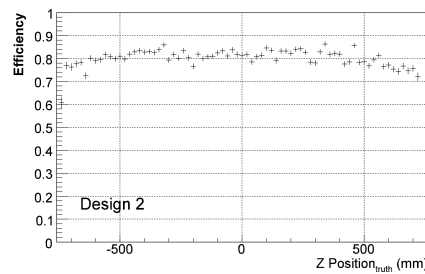
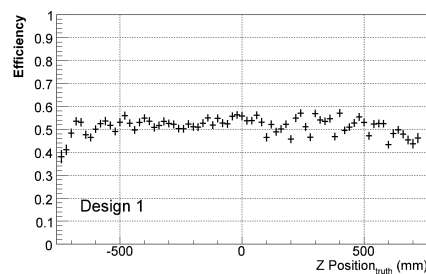


83.4%



Spatial Dependence of Neutron Id

Vertical Dependence

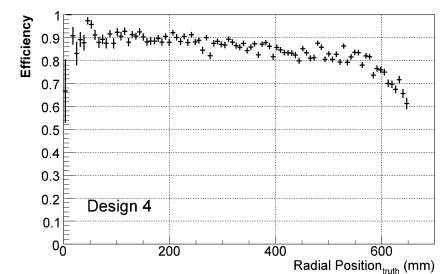
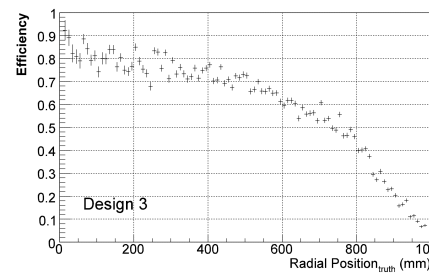
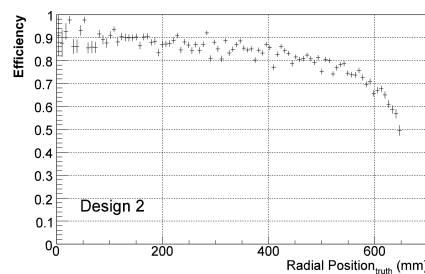
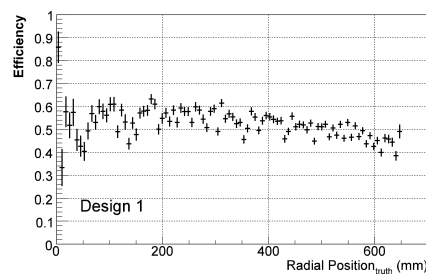


Design 1

Design 2

Design 3

Design 4

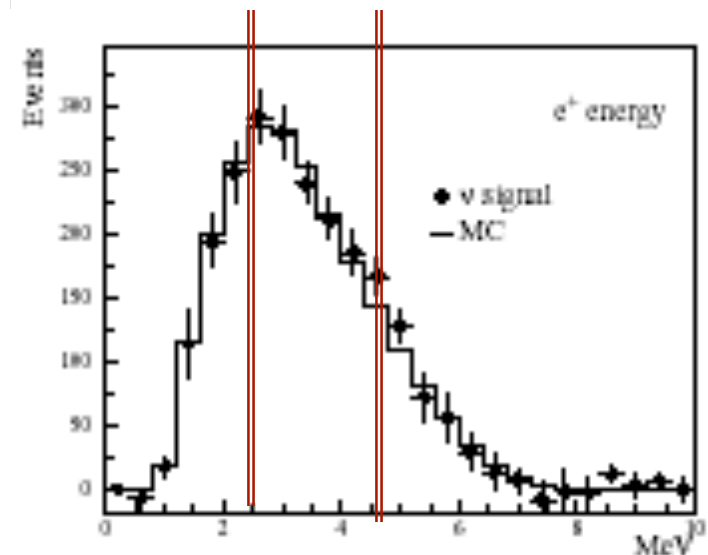
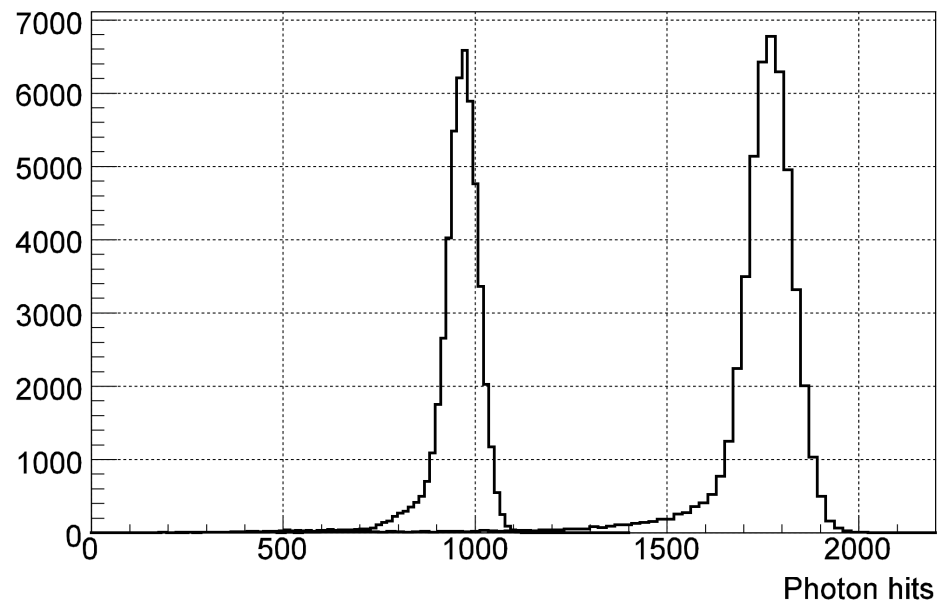


Radial Dependence



Positron Energy Response

Kinetic Energy = 1.5 MeV 3.5 MeV
Visible Energy = 2.6 MeV 4.6 MeV

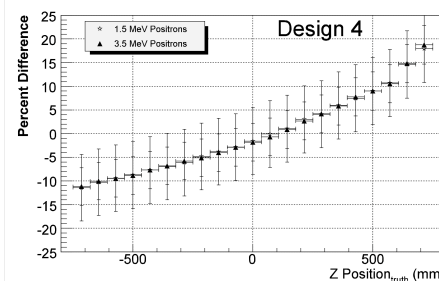
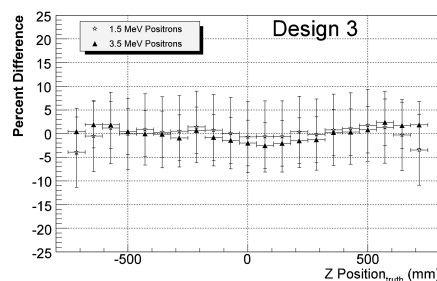
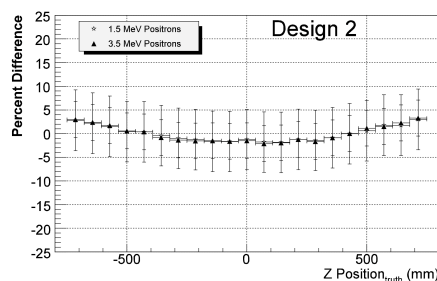
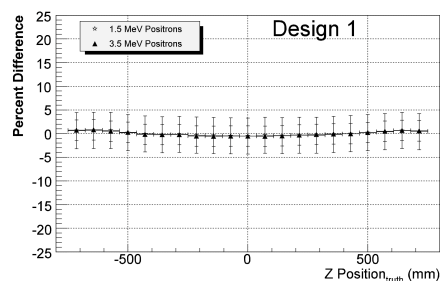


Initial study of 1—5 MeV positrons showed linear energy response, so we focused on these two energies for more detailed studies



Spatial Variation in Positron Response

Vertical Dependence

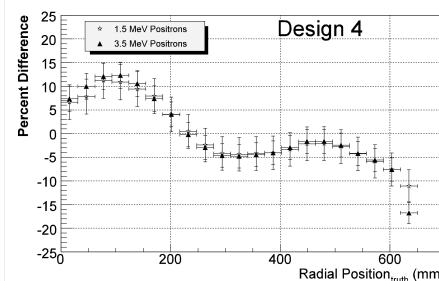
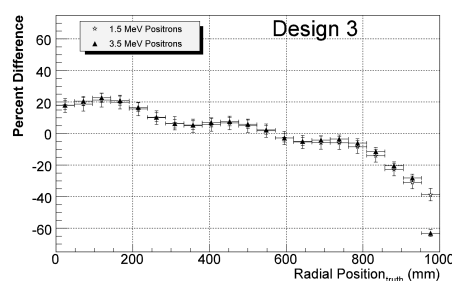
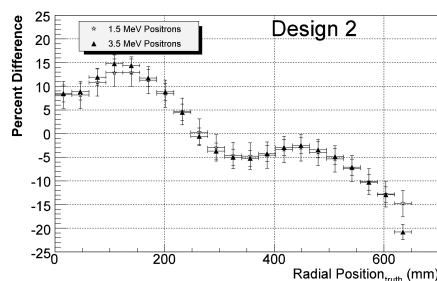
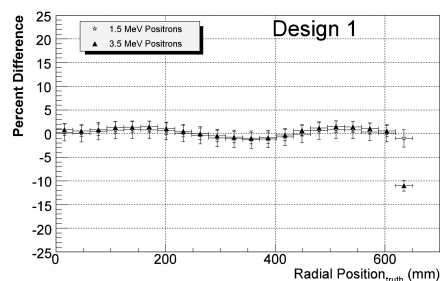


Design 1

Design 2

Design 3

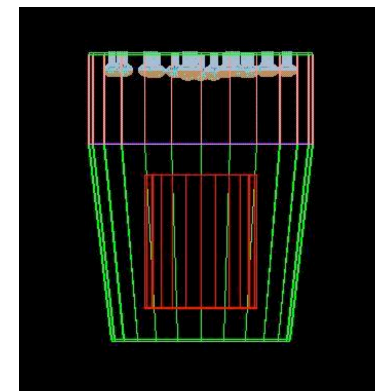
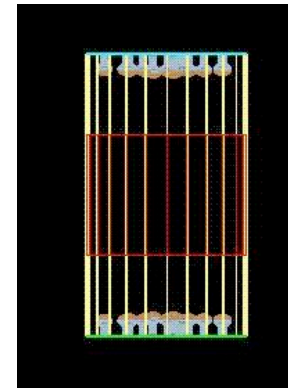
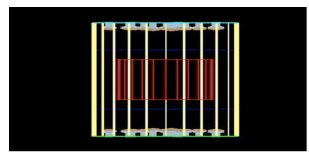
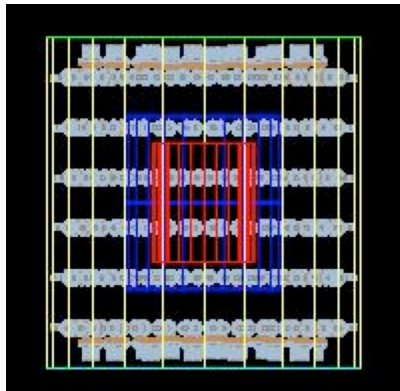
Design 4



Radial Dependence



Summary: An Optimal Design Will Depend on the Specific Goals



Design 1

Design 2

Design 3

Design 4

Footprint	4 x 4.2 m	2 x 4.2 m	2 x 3.5 m	2.5 x 3.2 m
# PMTs	282	30	30	24
Effective Fiducial Volume	0.93 m ³	1.42 m ³	2.15 m ³	1.51 m ³
Positron Response	±1%	±15%	±30-40%	±15%

A Document with all details is under preparation

